A Study of Junior High Students' Perceptions of the Water Cycle

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ABSTRACT

This study explored junior high school students' perceptions of the water cycle. The study sample included 1,000 junior high school students (7th-9th grades) from six urban schools, in Israel. The data collection was based on a series of quantitative and qualitative research tools that were specifically developed for this study.

The findings indicated that the students understand various hydro-bio-geological processes, but most of them lack the dynamic, cyclic, and systemic perceptions of the system. Moreover, they possessed an incomplete picture of the water cycle including many preconceptions and misconceptions about it. Most of the sample population studied were aware of the atmospheric part of the water cycle, but ignored its groundwater part. Moreover, those who included part of the underground system in the water cycle perceived the underground water as static, sub-surface lakes.

It is suggested that the findings reflect the traditional disciplinary approach of the dealing with subject of water in the science curricula. This study also implies the need for further research about the cognitive abilities of junior high students to deal with cyclic-systems thinking, and the need to explore activities that might develop or stimulate such abilities.

INTRODUCTION

The current study investigates the development of a curricula unit for The junior high school level, in which the topic of water in its environmental context, namely the "water cycle within the earth systems" was chosen as its major concept.

Kali, et al. (2003) suggested that environmental topics that are related to the hydrosphere should be presented within the context of the relationships between the hydrosphere and the other components of the earth's systems. For example, the water cycle is a complex system. In order for students to understand it meaningfully, they must understand the following relationships between the earth's spheres: (a) the hydrosphere and geosphere (e.g., chemical weathering by dissolution and precipitation of minerals from seawater); (b) the hydrosphere and atmosphere (e.g., evaporation and condensation); and (c) the hydrosphere, biosphere, and atmosphere (e.g., transpiration).

According to the constructivist approach, a meaningful learning process involves the interpretation of new information in light of existing ideas and beliefs (Driver and Oldham, 1986). Moreover, many of our initial beliefs and perceptions are quite different from the accepted scientific point of view. Therefore, a large portion of science education research that has been carried out in the last two decades, focused on identifying these "misconceptions" or "alternative concepts" (Greeno, Collins, and Resnick, 1996). Also, this approach suggests that any curriculum development undertaking should begin with a pre-development study in order to identify any misconceptions, preconceptions, and learning difficulties associated with the specific subject.

The following literature review will discuss research that deals with students' perceptions of the water cycle in relation to three possible origins of frameworks: (a) alternative frameworks that derive from the way of teaching, (b) alternative frameworks that derive from cognitive aspects and (c) alternative frameworks that derive from the context of teaching.

Alternative Frameworks that Derive from the Way of Teaching - The literature suggested that students over-simplified the water cycle to the reciprocating course of water from clouds to sea, and back to clouds. For example, Fetherstonhaugh and Bezzi (1992), who used the repertory grid method, reported that students described groundwater as "not running or moving" and "water captured in impervious rock". Similarly, Agelidou et al. (2001) reported that most of the students in their research held a perception of the groundwater as static, sub-surface lakes.

Undoubtedly, a major source of the above alternative frameworks is the level of abstraction that is needed to understand hidden phenomena and processes. (that take place underground). It seems that the students' mental model of groundwater as a static sub-surface lake, results from their actual experience with the upper water system. Marques and Thompson (1997), who studied the perceptions of Portuguese secondary school students in relation to some other aspects of the earth sciences, arrived at a similar conclusion. They found that students incorporate a resemblance of a bowl in order to explain that "the depth and mass of water become greater toward the center of oceans". Marques and Thompson suggested that the students used external observable features that relate to their own experience to explain hidden processes and phenomena. Similar results were reported by Agelidou, et al. (2001), who argued that empiricism constitutes an obstacle when trying to construct an effective representation of the water cycle, since the complex concept of a cycle is not based on empirical facts. More specifically, they suggested that this obstacle could also explain why most of the students produced deficient schemes of the water cycle which for example lacks ground water, water in the atmosphere, and water in living organisms.

Alternative Frameworks Which are Cognitive-driven - Kali, et al. (2003) suggested that students' understanding of the dynamic and cyclic nature of the earth's crust is influenced by their ability to synthesize components into a coherent system. The cyclic thinking is the ability to perceive the transformation of matter, within and among the earth systems, as a part of a cyclic process, where the overall amount of matter is being conserved. This perception also includes the understanding that there are no beginning or end points within the cycle (Gudovitch, 1997; Kali, et al. 2003). However, most of the published research concerning students' perceptions of the water cycle, did not take into consideration the nature of its cyclic-dynamic system.

Orion, (2002) and Gudovitch, (1997) indicated the cognitive aspects that are involved within the educational approach for the earth systems. Those cognitive aspects include high-order thinking skills such as systems-cyclic thinking and the perceptions of magnitudes, proportions, and rates of processes within and among the various earth systems. Similarly, Agelidou, et al. (2001) used students' difficulties in perceiving slow processes, which evolve during intervals of space that are not captured by the human eye, in order to explain why most of the students in their study did not perceive the results of erosion caused by water. Students' perceptions of the cyclic nature of water was expressed in their characterization and examples of a cycle, which referred to cycles in time - life cycle and seasons cycle - rather than cycles of matter. Boschhuizen and Brinkman (1995), who studied another sample of 15-17 year old students, reported similar finding. Their study showed that less than 10% of the students linked the concept cycles to earth cycles such as the water cycle, climate change or carbon cycle. These results indicate that most of the students enter junior high school without an efficient mental model that allows them to deal with the types of cycles that are part of environmental situations.

Alternative Frameworks that are Derived from the Context of Teaching - In contrast to the poor acquaintance of the students with the geospheric components of the water cycle, most of the 8th and 9th grade students stated in the questionnaire that, for example, evaporation is a familiar and understandable process. Furthermore, Bar (1989) and Bar and Travis (1991) studied the perceptions of 5 to 15 year-old Israeli students regarding the atmospheric component of the water cycle. They found that the perceptions of condensation and evaporation were developed simultaneously around the age of 11. Yet, Fetherstonhaugh and Bezzi (1992) reported that junior high students expressed difficulties in understanding the process of evaporation in its natural context, and believed that "water vapor is made when the sun is out". Bar (1989) and Bar and Travis (1991) suggested that understanding the physical concepts concerning the phase change, depends on the development of the ability to conserve water and air. Similarly, Johnson (1998a) and Johnson (1998b) suggested that the basis for students' understanding of the water's change of state should be the understanding the "particle model", which emphasizes the particulate nature of substances. Both Bar and Galili (1994) and Johnson (1998a and 1998b) indicated that even though some students did understand the particle model of matter, they still had difficulties to explain the process of evaporation in nature, in reality. Hurd (1998) argues that most of the science curricula in schools are descriptive and focus on laws, theories, and concepts of what is presumed to be discrete disciplines. By way of contrast, a "live" curriculum enables the students feeling of involvement in their own development, and recognizes their ability to use what they have learned.

PURPOSE

The purpose of this study was to reveal the alternative frameworks used by students in order to understand the various aspects of the water cycle. To be more specific, we have defined the following two research objectives:

1. To identify junior high-school students' previous knowledge and understanding of issues concerning the relationship between humans and the water cycle.
2. To explore students' perceptions of the cyclic nature of the water cycle.

METHODS

Sample - The sample population of the predevelopment study included about 1,000 junior high school students (7th-9th grades) from 30 classes of six different Israeli urban schools.

All the students from this sample learned about water in general, and the water cycle in the elementary school where the water cycle is a pivotal concept. However, the modules that exist emphasize mainly the upper ground sub-cycle, in its physical context (e.g., evaporation, condensation, and precipitation). Some textbooks also deal with environmental or biological aspects of water. Yet, these topics are not incorporated into the water cycle framework. In addition, these modules are mainly textual-based and include only a few hands-on activities-in the lab or outdoors.

Research Tools and Data Analysis - The data collection was based on a series of quantitative and qualitative research tools that was specifically developed for this study. In order to examine students' prior knowledge and understanding in relation to the water cycle, a zoom-in type of analysis approach was conducted (Gudovitch 1997). Quantitative research tools were used with a large sample in order to obtain a general picture of the students' knowledge and perceptions. Later, qualitative research tools were used with a smaller sample which was selected randomly from the larger sample. The aim was to get some insight of the student's knowledge, "misconceptions" or "alternative concepts" and also to validate the quantitative tools.

Five types of research tools were used in this study: Likert type questionnaires, open questions, drawings, word associations and interviews. Following is a brief description of the different tools. A detailed description of the development and analysis of these tools appears in Ben Zvi Assaraf & Orion, (2005).

Likert-type Questionnaires - Four different questionnaires were developed specifically for this study. In all of them the students were instructed to mark their level of agreement with a list of statements on a scale of 1-5. Since various statements had different numbers, they were standardized to a rank of 100% for easier comparison and are being reported as such in this paper.

A Groundwater Dynamic Nature Questionnaire (GDN): To identify students' previous knowledge and understanding of the dynamic nature of the groundwater system and its environmental relationship with humans.

A Cyclic Thinking Questionnaire (CT): To identify students' previous perceptions of the cyclic nature of the hydrosphere and the conservation of matter within the earth systems

The Global Magnitude Questionnaire (GM): To identify students' previous perceptions concerning the quantity of each component of the water cycle

A questionnaire for Assessing Students' Knowledge (ASK): To identify students' previous perceptions

Statements	Level of Agreement		
	Agreement %	Uncertainty %	Disagreement %
1. Most of the underground wter remains in the small pores of the rock, similar to a well-watered sponge.	25.7	43.4	31.0
2. Underground water is similar to underground lakes: It's located in deep spaces under ground.	49.5	26.6	23.9
3. The composition of rocks do not influence the composition of the water that passes through them.	46.9	29.7	23.5
4. Water can penetrate rocks only through cracks.	28.8	23.1	48.2
5. Groundwater can be found only in rainy climate areas.	22.4	37.4	40.2
6. Many industrial plants allow their sewage to flow into streams and thus pollute the water.	11.9	15.3	72.9
7. Some of the wells of Israel contain undrinkable water.	5.6	31.1	63.3

Table 1. The distribution (percentage) of students' conceptions of items regarding the dynamic nature of the groundwater system and its environmental relationship with humans (GDN).

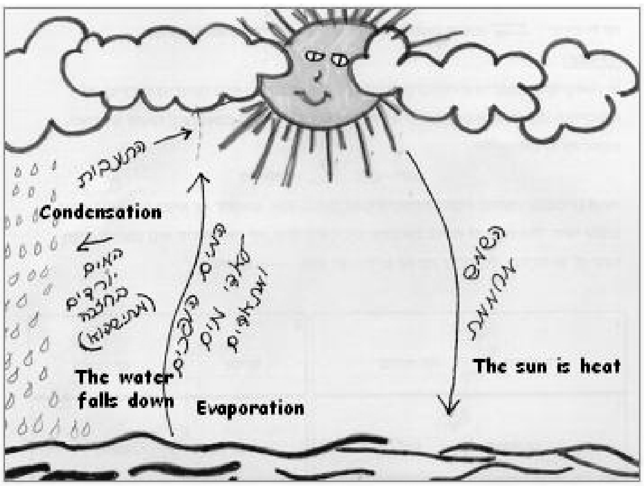

Figure 1. A drawing that reflects a naïve preception of the water cycle.

concerning the physical and chemical processes within the water cycle.

Drawing Analyses (DA) - In the current study, the students were asked to draw the water cycle. They were instructed to incorporate in their drawings as many items as possible from a given list of stages and processes of the water cycle. Students' drawings were analyzed using a coding framework prepared by Rennie and Jarvis (1995) and Ben Zvi Assaraf & Orion, (2005).

Word Association (WA) - In the current study students were asked to write down all the concepts regarding the water cycle with which they were familiar. The concepts were later classified according to Ben Zvi Assaraf & Orion, (2005).

Interviews - 40 students were interviewed, once their questionnaires were analyzed. During the interviews, all the students had to read their own answers, and to say whether they still agreed with their drawings or their responses to the questionnaire's statements, and to elaborate on their answers.

RESULTS

Since no significant difference was found between grades regarding any of the research tools, we combined the different grades data into one sample. Following is the data analysis under the five categories that have emerged from the content analysis of the interviews.

Students' Acquaintance with the Components of the Water Cycle - The findings indicate that most of the students have an incomplete, naive at times, perception of the water cycle and many misconceptions. Figure 1 represents typical drawings, where students presented only the atmospheric component of the hydro cycle (i.e. evaporation, condensation, and rainfall) and ignored the groundwater component (Figure 2). An analysis of 177 drawings indicates that about 70% of the students did not identify groundwater as a component of the water cycle, even when they were familiar with the associated terminology. Less than 10% of the students included components of the biosphere such as humans, animals, and plants. Similarly, less than 10% of the students included components that reflect the interaction between humans and the water cycle such as water consumption, housing, wells, sewage, and water pollution.

Analysis of the word association questionnaire revealed that here again, the most common concepts were those that take place in the atmosphere, namely rain, clouds, and evaporation. Less than one-third of the students mentioned concepts that are connected with one or more of the other components of the water cycle such as the geosphere, biosphere, change of state, and earth phenomena such as climate and weather, as well as environmental aspects.

Students' Understanding of the Dynamic Nature of the Water Cycle - Analyses of the students' drawings indicated that 67% of the students (out of 50% of the whole sample) who included the groundwater system in their drawings described the groundwater as a static, sub-surface lake. Furthermore, they perceived underground water as a disconnected system, wherein the water has no relationship with the surrounding rock. Moreover, only a third of the students' drawings presented a vertical dynamic model of the water movement, whereas most of them described this movement as underground rivers (Figure 3). The analysis of 45 interviews revealed that only 21% of the students thought that the rain, which penetrates through the rocks, may move under the ground horizontally toward the sea.

Similarly to the drawings and the interviews, the analyses of the Groundwater Dynamic Nature Questionnaire (GDN) revealed that only 25% of the students conceived of a scientific model of underground water movement through porous rocks (item 1 of Table

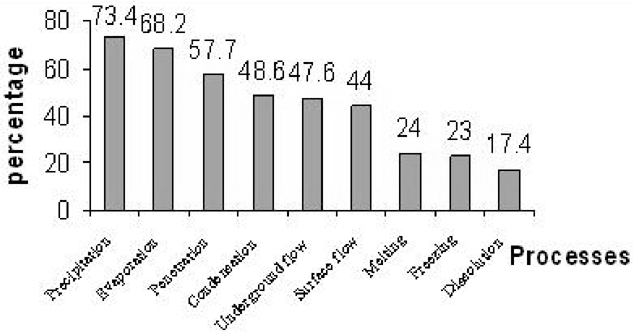

Figure 2. Student's perceptions of the water cycle as shown in their drawing. N = 956.

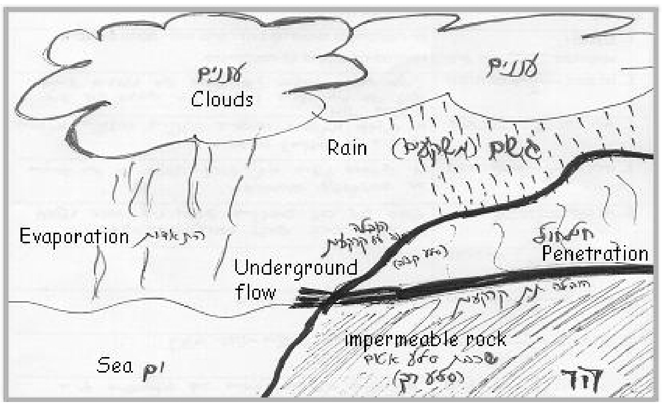

Figure 3. A drawing that presents groundwater movement as underground river.

1). 70% of the students explained their choice in sentences like: "Groundwater exists beneath the rocks and only passed through the rocks"; "There is no water in rocks"; "Groundwater exists in large spaces". Most of the students claimed that underground water could be found only in rainy areas and less than 10% of them used underflow or water penetration as a mechanism that can allow the movement of underground water from place to place. In fact, in order to explain the presence of groundwater in arid areas, most of the students used an upper ground 'River flow' model. In this model water flows from rainy areas by rivers to arid areas, where it penetrates the soil, and performed as groundwater.

The interviews revealed that because of the static perception of the students' of the underground water they failed to associate human activity with water quality. Similarly, in the GDN, only 40% of the students acknowledged the influence of humans on the quality of water pumped from wells (item 7 of Table 1).

Students' conceptions of the distribution of water on Earth - An analysis of the Global Magnitude Questionnaire (GM) revealed that about 50% of the students agreed that the amount of water that exists in rocks in the earth is higher than the amount of water that exists in lakes and rivers. Yet, 92% of the students could not give a scientifically correct explanation for their choice (item 3 of Table 2). Some of their "scientifically incorrect" explanations were "there is no water in rocks" and "because the lakes cover a bigger area on earth than the rocks". Explanations which were scientifically more correct included statements such as "because water does not evaporate from the rocks like (they evaporate) from lakes"; "in the earth there is a large amount of rocks and therefore a huge space for water.

However, an analysis of part B of the GM revealed a slightly different picture. It was found that most of the students possessed an incomplete picture of the water distribution on earth. For example, on a scale from 1 to 12, about 80% of the students claimed that the amount of available water that exists in rocks is small and even smaller than the amount of water that exists in rivers or lakes (Figure 4).

Most of the students exaggerated in their evaluation of the contribution of humans to the water cycle. For example, about 50% of them ranked the partial amount of sewage water and water in the human body much higher than their actual values. Consequently, they ranked them on a scale in places 1-8 out of 12 (Figure 4), whereas the correct ranking should have been 12, since the relative amount of water in the human body compared to the total amount of water on earth is negligible. In the interviews students claimed that: "since there are at least six billion people all over the world and water makes up 75% of the human body weight, a huge amount of water exists in all human bodies".

Students' Understanding of Physical and Chemical Processes Within the Water Cycle - The analysis of the data indicated that students in all grades had misconceptions concerning basic physical and chemical processes such as evaporation, condensation, and dissolution, which are important for understanding the transportation of matter within the water cycle. About 80% of the students did not agree with the statement "if we put a glass of water in a refrigerator for one week, the amount of water in the glass will decrease due to the evaporation process" (item 3 of Table 3). The dominant explanations were "maybe when cold, the water does not evaporate"; "water evaporates in heat only"; "the temperature in the refrigerator does not enable evaporation".

Furthermore, analysis of the data implied that students perceived the chemistry of water as a constant throughout the entire water cycle. About half of the students did not agree with the statement "the composition of a cloud that has been formed above the "Sea of Galilee" is different from a cloud that has been formed above the "Dead Sea" (item 1 of Table 3). Yet in the explanatory questionnaire, only 40% of the students claimed that "all the clouds are similar to each other"; "evaporating water is always sweet water" or "water evaporates without the salts and therefore the content of the clouds is equal".

Students' Understanding of the Cyclic Nature of the Water Cycle - The results point the students' inability to define a cyclic process and to give an example that reflects their definition. Less than 10% of the students mentioned a cyclic component in their definitions. In fact, one-third of the students could not provide any characteristic of a cyclic process. This result may imply the students' lack of experience with cyclic phenomena in the science curriculum. Another aspect of this phenomenon was found in the students' perceptions of the characteristics of the cyclic process. For example,

Statements	Level of Agreement		
	Agreement %	Uncertainty %	Disagreement %
1. Most of the water in our planet is the salty water in the oceans and is not available to use for humans.	12.6	23.6	63.8
2. It rains mostly over the oceans and only a little bit over the land.	36.6	36.0	27.3
3. Rocks contain much more water than lakes and rivers together.	47.7	46.5	5.8
4. The amount of water that exists in seqage produced by man is much less than the amount of water that exists in the groundwater.	26.4	59.2	14.4
5. The amount of water that exists in sewage produced by man is much less than the amount of water that exists in all rivers and lakes.	22.3	54.1	23.6

Table 2. The distribution (percentage) of students' perceptions as shown in a Global Magnitude Questionnaire (GM).

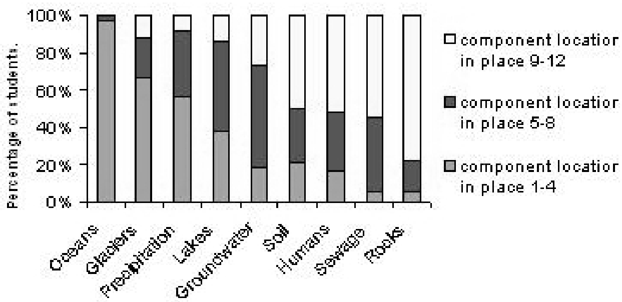

Figure 4. Students' preceptions as shown in a Global Magnitude Questionnaire (GM).

more than 50% of the students claimed that the water cycle has a beginning and an end. (item 1, Table 4). In the explanatory questionnaire the common responses were "it's not true because A and B are the beginning and the end points, respectively", or "there are additional beginning points". Only 24% of the students suggested a more progressive view such as "in the cycle, there are no beginning and end points" or "a cyclic process never ends" (item 1, Table 4). Similarly, in the interviews most students claimed, "There must be a beginning point …the end point, I don't know." or "The end point could be either the sea or the groundwater". Consequently, most of the examples of cycles that were given in the open questionnaire referred to cycles in time such as the life cycle, or season cycle, and the food chain was the only cycle of matter that was mentioned.

Most of the students did not realize that in a cyclic process, the overall amount of matter is conserved. For example, in the CT only 44.2% of the students did not agree with the statement "the amount of water in the ocean is growing from day to day because rivers are flowing continuously into the ocean" (item 2, Table 4). In addition, most of the students did not incorporate a mechanism of transformation of matter in their explanation. For example, although only 40% of the students agreed that global warming can affect the amount of water on earth (item 5, Table 4), less than 30% of them included any kind of mechanism of matter transformation in their explanation. Furthermore, despite of students' acquaintance with the evaporation process, they minimized its influence as a natural phenomenon. For instance, only about one-third of the students mentioned evaporation as a mechanism of transferring water from the ocean to the atmosphere (item 2, Table 4). A common expression that emerged during the interviews was "true, water evaporates from the ocean, but the total amount of water that evaporates is too small". An additional example of students' difficulties to conceive the nature of evaporation as a valid mechanism of the transformation of matter within the water cycle is reflected in their drawings. Only 13% of the students, who included in their drawing rivers, lakes or springs indicated the evaporation process in regard to these water resources, specifically A significant positive correlation was also found between the students who included groundwater flow in their drawings and those who demonstrated cyclic thinking in their questionnaires (Table 4). Students who drew the groundwater in their drawings (P=0.02) also believed that in a cyclic process the overall amount of matter is being conserved (item 2, Table 4). This result may indicate that the groundwater flow is a crucial mechanism in students' perceptions of the cyclic nature of the water cycle.

It is suggested that the students' difficulties in understanding the proportion of the various reservoirs in the water cycle, could be influenced by their habit to exaggerate the contribution of humans to the water cycle. For instance, in the explanatory questionnaire, 64% of the students claimed that "the larger the number of people who live, the larger amount of water is consumed"; "people will use more water than water is being consumed, thus water will disappear" (item 6, Table 4). Twelve percentages of the students intuitive suggestion was that "people don't need a lot of water" or "there is plenty of water on earth". Whereas, 24% of the students gave a progressive explanation such as "human beings have only a slight effect on the global amount of water" or "the quantity of water on earth is constant, only water quality is being changed". These results revealed their difficulties to understand people as being only a part of the natural system, rather than being its ruler.

DISCUSSION

The use of various research tools and methods together with the adequate sample size enabled us to identify a lot of alternative frameworks that junior high school students in Israel possess in relation to almost every aspect of the water cycle. The high level of agreement

Statements	Level of Agreement		
	Agreement %	Uncertainty %	Disagreement %
1. The composition of a cloud above the Sea of Galilee is different from that of a cloud above the "Dead Sea"	28.0	24.3	47.7
2. A cloud is composed of water vapors (water particles that appear as a gas) and not of water droplets.	53.7	24.0	22.3
3. If we put a glass of water in a refigerator for a week, the amount of water in the glass decreases due to evaporation.	48.9	30.5	20.7

Table 3. The distribution (percentage) of students' perceptions as shown in the Knowledge questionnaire (ASK).

Statements	Level of Agreement		
	Agreement %	Uncertainty %	Disagreement %
1. In the water cycle, the beginning point is the oceans and its end point is the underground water.	54.6	27.7	17.7
2. The amount of water in the ocean grows from day to day because rivers are flowing into the ocean continually.	26.3	29.6	44.2
3. The increase in waste that man produces causes an increase in the Earth mass (weight).	22.5	26.9	50.6
4. Massive mining (quarrying) of minerals causes a decrease in the Earth's mass (weight).	10.9	34.5	54.5
5. The increased evaporation as result of the Earth's global warming effect, may lead to a decrease in the amount of water on Earth.	39.1	25.9	35.1
6. If the population on Earth will continue to grow, water consumption will increase, thus the amount of water will decrease.	60.1	21.9	18.0
7. The amount of water that evaporates from the entire surface of the Earth into the atmosphere is not equal to the amount of rain that falls on the Earth's surface.	19.8	64.7	15.6

Table 4. The disribution (percentage) of students' perceptions are shown in a Cyclic Thinking Questionnaire (CT).

that exists among the findings of the different research tools reinforces the reliability of our results.

The most striking finding of the current study is that most of the Israeli students enter junior high school with a partial and fragmented conception of the water cycle and graduate from it with almost the same misunderstandings. This finding is surprising since water is a central issue in Israel's science curricula at the elementary school and junior high levels. In the following section we will discuss some potential sources for the findings and how they might affect the way the topic "water" is taught in the "Science for all" era.

More specifically, we will discuss our findings in relation to three possible origins of frameworks: (a) alternative frameworks that are derived from the way of teaching, (b) alternative frameworks that are mainly cognitive driven and (c) alternative frameworks that are derived from the context of teaching.

Alternative Frameworks that are Derived from the Way of Teaching - All the data collection sources and most of the students' drawings indicate that most of the students made no connections between the atmospheric water cycle and the geospheric underground water cycle. The Israeli students who participated in this study in elementary school were presented with a fragmented framework of the water cycle. For example, in a very popular book for elementary school, the water cycle drawing is very similar to Figure 1 and the following text is mentioned under the drawing: "The water in the land and ocean evaporates. Water vapors condense to make clouds that later on create precipitation. The water flows in the river to the ocean". Note that another part of this book deals with the groundwater system. However, no connection was made between the underground and upper ground subsystems of the water cycle. This fragmented perception explains, of course, the students' difficulties in presenting environmental topics such as: the impact of industrial areas, landfills and gas stations on groundwater quality, within the context of the interrelationships of the hydrosphere and other components of the earth's systems.

Another very common alternative framework that was noted from the students' drawings and interviews was their static perception of the groundwater. Although we agree with the cognitive source of this alternative framework, we preferred to include it under the category of the way of teaching, since it is possible to deal with hidden phenomena such as the underground water through the use of 3D models. While working with such models, students could confront their alternative conception through instructional and constructed activities and self-investigation. However, such 3D models were not existed within both elementary and junior high science teaching during the years of our study. Such models might be expensive and not very simple to operate in small groups yet, without a conceptual change that such concrete experience can induce, most students are not able to translate environmental phenomena to the higher level of relationships among components of the water cycle. The concrete experience, in relation to the geospheric component of the water cycle, can be achieved easily through first-hand experiences with rocks and soils. Unfortunately, such activities were also uncommon during the years of our study.

Alternative Frameworks Which are Cognitive-driven - Our analysis suggests that students perceive the "water-cycle" as a set of unrelated pieces of knowledge. They understand various hydro-bio-geological processes, but lack the dynamic perception, cyclic, and systemic nature of the system. It is suggested that the perception of the water cycle as a coherent system involves the operation of two higher-order thinking skills, namely cyclic and systems thinking. Students' perceptions of the cyclic nature of water was expressed in their characterization and examples of a cycle, which referred to cycles in time (life cycle and seasons cycle) rather than cycles of matter..

We argue that students' understanding of the cyclic nature of the water cycle is influenced by their ability to synthesize its components into a system. Specifically, the cycle can be constructed by identifying the relationships and connections among the components. These connections serve as a mechanism by which students can create an entire cycle. The quality and quantity of the connections that they create within a system are influenced by their knowledge about each component in the system, as in, the interrelationships between the type of rocks and the water quality of the groundwater. The water distribution questionnaire and the drawings revealed the students' alternative framework of the relative sizes of the various water reservoirs on earth, as well as their overestimation of the relative influence of man on the natural earth systems. These findings are identical to those of Gudovitch (1997) that were conducted among 11th and 12th grade students in relation to the carbon cycle.

These cognitive constraints, which affect high-school students as well, might lead one to think that the cognitive level of junior high-school students is premature to study such complexed systems as the water cycle. This notion should be tested by additional studies. Yet, Kali, et al. (2003), who studied the ability of 7th grade students to construct the dynamics of material transformation within the rock cycle, suggested that using an effective learning strategy enables students to overcome such cognitive constraints. They reported a substantial improvement of 7th grade students toward the higher part of the systems-thinking continuum, as a result of knowledge integration activities. It is suggested that similar knowledge-integration activities could also be used for constructing the water cycle as a dynamic, cyclic system.

Alternative Frameworks that are Mainly Derived from the Context of Teaching - The third group of alternative frameworks that was found by this study is related to concepts that students understand independently, but are not related to the context of the water cycle. For instance, in contrast to the students' poor acquaintance with the geospheric components of the water cycle, most of the 8th and 9th grade students stated in their questionnaires that evaporation is a familiar and understandable process. Yet, the current study indicates that most of the junior high students expressed difficulties in understanding the process of evaporation in its natural context and tended to claim that evaporation could not occur at low temperatures.

The analysis of the students' drawings and association diagrams revealed an additional aspect of their difficulty in incorporating school learning with real world phenomena. Almost all of the students ignored the human influence on the water cycle in their assignments, whereas the interviews indicated that most of the students were aware of the water pollution caused by humans. Dove, et al. (1999) reported that students who lived near polluted rivers drew rivers in a rural pastoral setting rather than incorporating components of human intervention such as pollution. These results suggest that students do not relate their school learning of the water cycle to their daily experience.

The above conclusion is quite surprising since there is no doubt that the water cycle is most relevant in our daily life, especially in a semi-arid area like Israel. Thus, it seems that dealing with a relevant subject is probably insufficient for making it relevant in the students' opinion. In order to reach this goal, it is suggested that perhaps the whole learning process should be conducted in such a way that the students will see its relevance from the first step throughout the whole curriculum.

Miles and Osborne (1998) suggested that scientific knowledge can best be presented in the curriculum as a number of key 'explanatory stories' that interest and engage pupils, and are able to communicate ideas in a way that make them coherent, memorable, and meaningful. These 'explanatory stories' use the narrative form to present ideas as a rounded whole by emphasizing that understanding is not just propositions or concepts, but interrelated sets of ideas that provide a framework for comprehension. Moreover, this approach helps to ensure that the central ideas of the curriculum do not become vague because of too many details. As a result both teachers and pupils can see clearly to where these ideas lead.

Hence, it is suggested that instead of dealing with the water cycle in terms of its physical and chemical processes, it should be learned as an example of 'explanatory stories' in an environmental-social context. Note that it is not suggested to omit the physical and chemical processes from the curriculum, but only to change the order of learning: First, to create the relevance and interest among the students and then teach the more abstract part of the scientific curriculum that is needed in order to solve a specific authentic problem.

Mayer (1995) contends that the "hard" science approach has been unable to provide adequate insight into the complex processes of the earth system, illustrating the severe limitations of reductionist science for studying processes as they occur in the real world. He suggested to adopt an earth system education framework for the development of integrated science curricula. Specifically, any physical, chemical, or biological process that future citizens must understand in order to become literate in science can and should be taught in the context from which the particular process was taken in the earth systems.

We contend that while learning science within the context of the real world, there is a crucial element in this notion that unfortunately is mentioned in a limited way in the STS theoretical literature: namely that there is no substitute for the real world than the real world itself. Therefore, any curriculum that deals with natural phenomena should use the outdoor learning environment as much as possible.

SUMMARY

This study revealed the following difficulties in understanding the systemic-dynamic nature of the water cycle:

Most of the students could not make a connection between the atmospheric water sub-cycle and the geospheric underground water sub-cycle.

Most of the students perceived underground water as a static, sub-surface lake, a disconnected system, wherein the water has no relationship with the surrounding rock.

Most of the students exaggerated the contribution of humans to the water cycle. Most of the students did not associate the relative size of the oceans with the amount of precipitation that falls in these areas.

Most of the students had difficulties to perceive the transformation of matter (water) in the earth reservoirs, and to synthesize components into a coherent system.

Most of the students did not relate what they learned at school about the water cycle with their daily experience.

It is suggested that in order to provide the future citizens with basic tools to deal with their environment, science education should emphasize studying natural cycles within the context of their influence on people's daily life, rather than isolate them into specific scientific domains.

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